Characterization and identification of glioblastoma progression on preoperative multimodal MRI

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ABSTRACT

Introduction:

The treatment failure of Glioblastoma (GBM) is mostly due to the inadequate identification of its invasive margin. We aimed to characterize the peri-tumoral area, the predominant site of tumor progression by using multi-modal MRI. Thereafter, a robust method to preoperatively identify regions progression was developed.

Methods:

We retrospectively included 38 newly diagnosed cerebral glioblastoma patients. All patients were treated with 5-aminolevulinic acid (5-ALA) fluorescence guidance surgery and standard postoperative concomitant chemoradiotherapy. Preoperative MRI data acquisition was performed using a 3T MRI. Imaging included volumetric post contrast T1-weighted, perfusion MR, and DTI. DTI was decomposed into isotropic (p) component and anisotropic (q) components. Follow up MRI at time point of progression were co-registered to the preoperative MRI. Imaging characteristics of the peritumoral tumor progression regions were selected and compared to 5mm peri-tumoral non-progression regions. These imaging characteristics were then used to undergo convoluted neural network training which was further applied to develop an automated drawing of the tumor progression map on the preoperative MRI.

Results:

Multimodal MRI characterization

FLAIR. In areas of later progression, there was significant increase in the FLAIR signal compared to non-progression area ($p = 0.003$) and control ($p < 0.001$).

Diffusion MR. Characterizing isotropic p component showed a significant decrease in progression area than contrast enhanced area and non-progression area ($p < 0.001$). In areas of progression, anisotropic q was lower than non-progression peri-tumoral area ($p = 0.001$) and control ($p = 0.009$). The ADC values in the progression area were lower than peri-tumoral non-progression area ($p = 0.008$) and control ($p < 0.001$). Fractional anisotropy (FA) showed no difference between progression area and non-progression area ($p = 0.537$).

DSC-MRI. Relative cerebral blood volume, compared to control, was increased in the contrast enhanced lesion and progression areas ($p < 0.0001$), but there was no difference in progression and non-progression area.

Identification of the tumour progression

By using the above significant imaging features to train the model, an average accuracy of 85.1% with sensitivity of 86.5% and specificity of 83.8% was achieved using the convoluted neural network. Further application of the trained model can be used to generate predicted areas of progression on the preoperative MRI.

Conclusion:

Multimodal MR imaging, particularly diffusion tensor imaging, can demonstrate distinct characteristics in areas of potential progression on preoperative MRI. Moreover, by using these imaging features, the site of tumor progression can be identified and drawn automatically via a trained machine learning model which provides a direction for future study and treatment target.